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A GLACIAL GRAVEL SEAM IN LIMESTONE AT RIPON, WISCONSIN[1]

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Just west of the city of Ripon (S.E. ¼ of N.W. ¼, Sec. 20, T. 16 N., R. 14 E.) is a limestone quarry belonging to Mr. William Kroll. This locality (Fig. 1) displays a phenomenon of unusual interest, namely, a seam and pockets of glacial gravel within the Paleozoic rocks.

In 1914 the writer visited this quarry in company with E. O. Ulrich, United States Geological Survey, W. O. Hotchkiss, state geologist of Wisconsin, and Edward Steidtmann. Further field work was done in 1915 in company with Lawrence Martin and Walter H. Schoewe, and in 1919. The writer is indebted to all of these persons for assistance, criticisms, and suggestions.[2]

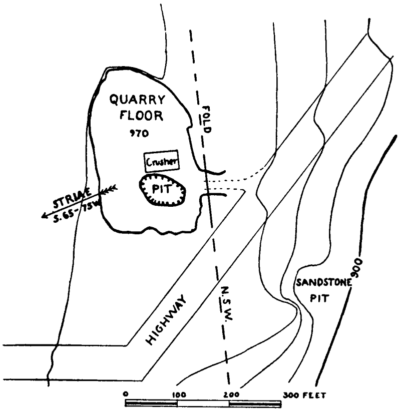

FIG. 1.—Sketch map of Ripon limestone quarry. Topography adapted from U.S. Geological Survey, contour interval 20 feet.

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[1] Published by permission of the state geologist of Wisconsin.

[2] Lawrence Martin, "The Physical Geography of Wisconsin," *Bull. 36, Wisconsin Geol. and Nat. Hist. Survey*, 1916, pp. 250–51.

A few rods east of the Kroll quarry, on the side of the hill which slopes to the east, is a pit in soft St. Peter sandstone which is overlain, at the top of the exposure, by a few feet of disintegrated Trenton dolomite. Within the sandstone are crevices and pockets filled with glacial gravel. Excavations at the bottom of the pit show the shaly and cherty zone characteristic of the top surface of the underlying Lower Magnesian formation which here dips about 30 degrees to the east.

In the Kroll quarry, on the hill to the west, 50 feet higher than the bottom of the pit, sandstone is seen at the entrance, overlain by a few feet of dolomite at about the same level as that to the east. At the eastern edge of the quarry proper is the monoclinal fold shown in Figure 2. The displacement is from 8 to 10 feet, down to the west, and the strike is N. 5° W. Less than 40 feet west of this fold is a pit in the main floor of the quarry 40 feet deep, which shows no St. Peter sandstone. The quarry well reaches sandstone at a depth of 100 feet (Fig. 3).

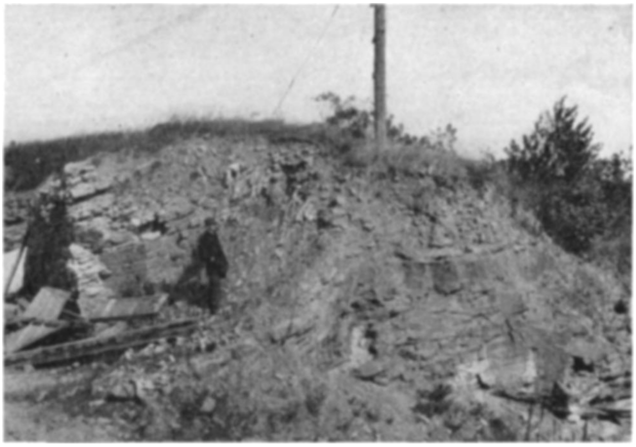

FIG. 2.—Fold at entrance of Ripon limestone quarry, looking north

In Figure 3, No. 1 is Lower Magnesian; Nos. 2 to 4 and 6 to 8, Trenton; and Nos. 5 and 9, Pleistocene; the sandstone in the well is Cambrian.

The gravel seam, No. 5, extends throughout the quarry, which is over 200 feet across. The dolomite layers above the seam are in no way unusual, but along the seam is considerable weathering so that the underlying rock is nearly everywhere disintegrated into a putty-like yellowish clay to a depth of an inch or two. It is this feature rather than the presence of gravel which makes this horizon so prominent, as is shown in Figure 2. The gravel and sand layer is best developed in the eastern part of the quarry. In thickness, the sand and gravel layer varies from a mere trace up to a maximum of about two inches (Fig. 4). The largest pebbles are about an inch in diameter. Dolomite, granite, greenstone, and quartzite were distinguished. Minute cross-bedding is locally observed.

9.	Glacial till	2–3 feet
8.	Gray, thin bedded dolomite	5.0 feet
7.	Bluish thin-bedded dolomite	4.5 feet
6.	Grayish-blue dolomite	0.8 feet
5.	Glacial sand and gravel maximum	0.2 feet
4.	Hard gray rather thin-bedded dolomite	5.3 feet
3.	Blue, heavier bedded dolomite with fossils; sandy at base	6.5 feet
2.	Sandy buff dolomite, forming a parting	0.5 feet
1.	Gray dolomite with layers of gray shale and sandstone. Irregular beds, the bedding in general dipping at low angles to the east	40.0 feet
	Total, about	63 feet

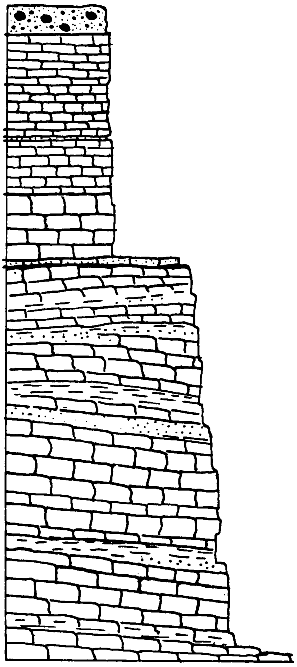

FIG. 3.—Section of Kroll quarry, Ripon, Wis.

In the sandstone pit to the east, larger gravel deposits are found filling gashes or irregular openings in the rock. Some of the openings are as much as three feet across and of irregular shape.

As No. 1 of the section does not contain fossils, the correlation of this section with that seen in the sand pit to the east is somewhat puzzling, but the evidence of the rocks and fossils, of the sloping surface of the Lower Magnesian seen in the sandstone pit, and a close study of the supposed fault unite in definitely proving that the St. Peter pinches out in the interval. Statements of Mr. Kroll regarding exposures formerly visible in a trench through the quarry floor also confirm this explanation. Similar phenomena without the complicating presence of folding are known elsewhere in the vicinity.[1]

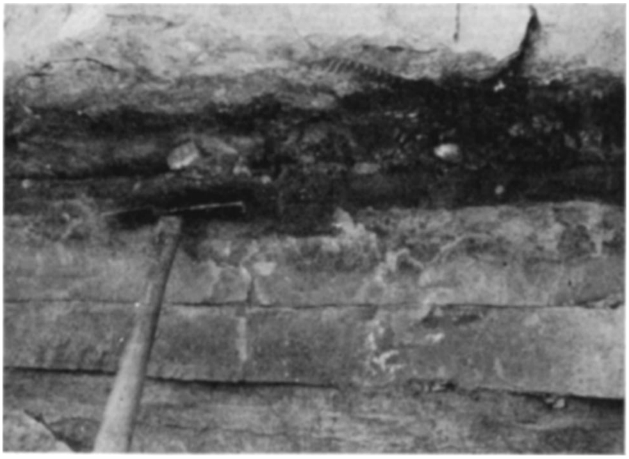

FIG. 4.—Close-up view of gravel seam, showing weathering of adjacent dolomite. (Photograph by W. O. Hotchkiss.)

Before considering the origin of the gravel seam, the question of the origin of the fold with which it is related may be considered. The fold might be due:

1. In some way to the pinching out of the St. Peter.
2. To glacial pressure on the east side of the hill, which forced up the wedge of St. Peter sandstone resting upon the sloping surface of the Lower Magnesian.
3. To the same processes which formed the major joints and the other faults and minor folds which are found in the Paleozoic rocks of eastern Wisconsin.

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[1] T. C. Chamberlin, *Geology of Wisconsin*, Vol. II (1877), pp. 270–75.

The direction of the movement which caused the fold is not in harmony with slumping of the St. Peter on the inclined surface of the underlying Lower Magnesian. The hypothesis of slumping might, however, explain the eastward-dipping slips and gashes in the St. Peter sandstone.

The forcing up by glacial pressure of a wedge of St. Peter upon the shaly surface of the underlying Lower Magnesian is a satisfactory hypothesis. The strike of the fold is N. 5° W., that of the glacial striae on top of the quarry S. 65–75° W., making an angle of 70 to 80 degrees. Somewhat similar phenomena are described by Chamberlin near Burlington, Wisconsin, and by Alden.[1]

Folds are known in the Paleozoic rocks of the region, as at the abandoned quarry in Fond du Lac, while faults are by no means uncommon. In many instances it can be definitely proved that these features far antedate the glacial period and are not due to ice work. It is therefore necessary to have more evidence than is now at hand to prove that these particular joints and folds at Ripon are different in age from those of the Driftless Area. The localization of the fold by the wedging out of the sandstone will fit with this hypothesis as well as that of glacial pressure.

The writer has therefore concluded that the fold is probably only in part due to glacial action but was principally caused by earth movements.

The following hypotheses may be considered in connection with the origin of the gravel seam between the dolomite layers:

1. Deposition of gravel in Ordovician times between layers of dolomite.
2. Glacial transportation of a slab of dolomite on to a previously planed-off surface, covering a small thickness of gravel.
3. Raising of frozen-together upper layers, possibly during the formation of the fold, followed by filling of the crack with gravel and subsequent settling back of the overlying rocks.
4. Entry of glacial or post-glacial gravel-bearing waters along a bedding plane.

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[1] T. C. Chamberlin, *Geology of Wisconsin*, Vol. II (1877), p. 203; Wm. C. Alden, "Quaternary Geology of Southeastern Wisconsin," *U.S. Geol. Survey, Prof. Paper 106* (1918), pp. 206–8.

The absence of similar deposits of proved Ordovician age, together with the lack of induration and the presence of the gravel-filled gashes in the sandstone, definitely eliminate the first hypothesis.

The second theory may be divided into three subdivisions: (*a*) distant source for the dolomite slab; (*b*) movement by rotation without transportation to any great distance; (*c*) slight lateral movement causing the opening of an irregular bedding plane by destroying the registry of the irregularities.

a) No nearby source for such a gigantic slab (at least two hundred feet square) can be found except on the hill northwest of the quarry, and a glacial movement from the northwest is impossible since the Driftless Area is not very far away in that direction. The glacial transportation without breaking of such an enormous piece of rock for any distance, as from across the valley to the east, is quite out of the question. The rock above the gravel seam is no more broken than is usual near the surface of the ground. The major joints, which strike from N. 5° W. to N. 30° W. pass right through the gravel seam (Figs. 5 and 6) and there seems no valid reason to assign a glacial or post-glacial age to them. In fact, there is no difference in the rocks above from those below the seam and no glacial striations are found on the under surface.

b) The second subdivision, namely, the inclusion of gravels by a rotary movement of the overlying rocks, is open to the same objections. It also necessarily involves the assumption of the glacial origin of the fold.

c) The opening of an irregular bedding plane by a slight movement, either rotary or lateral, which destroyed the registry of the irregularities is a possibility. The seam is, however, very regular; moreover, the glacial or post-glacial origin of the joints must be presupposed under this hypothesis.

The third view, the raising of the overlying beds by glacial action thus opening a seam, as one opens the leaves of a book, offers the fewest difficulties. However, it seems impossible that such a process could avoid moving and breaking the overlying rocks. A further difficulty is the comparatively regular thickness of fine gravel. If the frozen upper layers were simply buckled upward by glacial pressure, as one would buckle a sheet of paper by pushing slightly on one side, the explanation is perfectly adequate. It is not even necessary to assume a glacial origin for the fold, for pressure with the beds in their present position would account for the phenomenon. The filling can be ascribed either to glacial or to post-glacial waters, under this view.

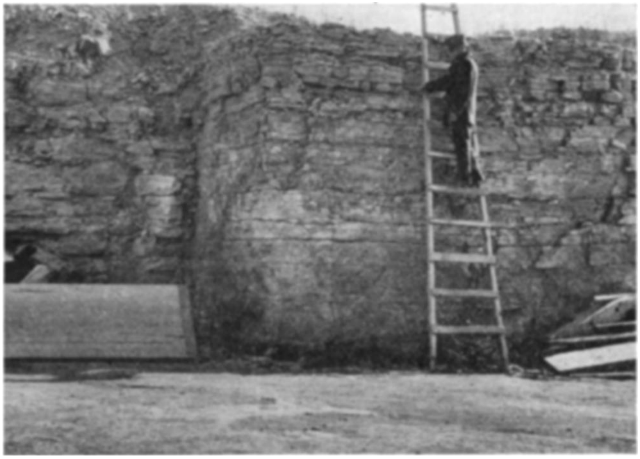

FIG. 5.—Gravel seam near entrance to quarry

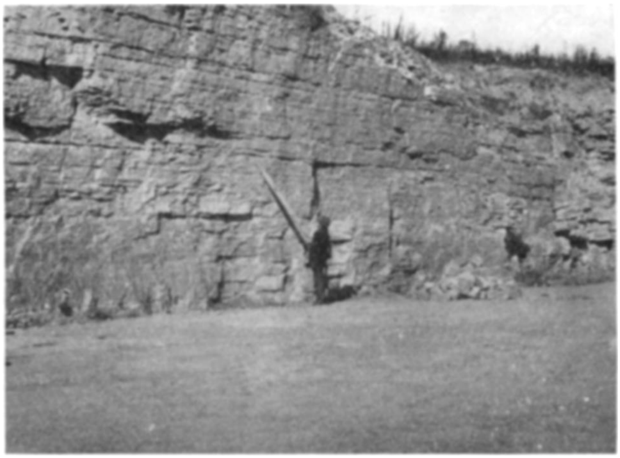

FIG. 6.—Gravel seam in west face of quarry, showing joints

Turning to the fourth hypothesis, it is significant that the gravel seam shows most weathering of all the bedding planes in the quarry, thus indicating that it has been a trunk channel for ground water. It is difficult, however, to understand, first, why the waters have followed only this particular plane; second, how they carried such comparatively large stones considering the size of the opening, and third, how they could produce so widespread and comparatively regular a sheet of gravel without at all affecting the large joints which pass through it. Being 10 feet below the surface, the seam is beyond the reach of frost under present climatic conditions unless air circulated through it, so that we cannot appeal with certainty to enlargement by freezing. It is possible that weathering of an originally soft layer has been the cause of lateral enlargement of the bedding plane parting so as to permit a widespread deposit of sand and gravel. In the case of the gashes and joints in the sandstone the effects of erosion by the gravel-carrying waters is clear, while the source of the filling might readily be the gravel deposit which overlies a portion of the exposure. The

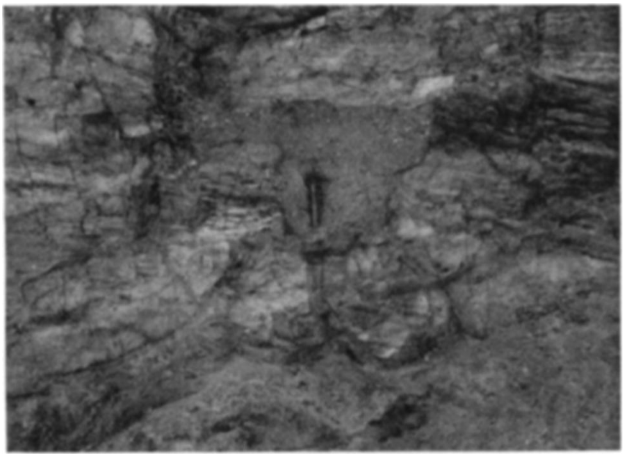

FIG. 7.—Glacial gravel pocket in St. Peter sandstone. (Photograph by W. O. Hotchkiss.)

position of the gravel seam in the quarry is not such, however, as to lend much support to this.

The writer has concluded that the balance of probabilities favors the view that the gravel seam is due primarily to glacial pressure, although solution has undoubtedly had a part in enlarging the parting. The gravel and sand may well have been in part deposited since the Glacial Period.